

Extradosed Prestressed Bridges

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AGENDA

- **The Extradosed Bridge Concept**
- **Representative Extradosed Bridges**
- **Key Proportioning Parameters and Design Considerations**
- **Case Study**
- **Concluding Remarks**
- **Questions**

What is an Extradosed Prestressed Bridge?

Odawara Port Bridge, Japan (1994)



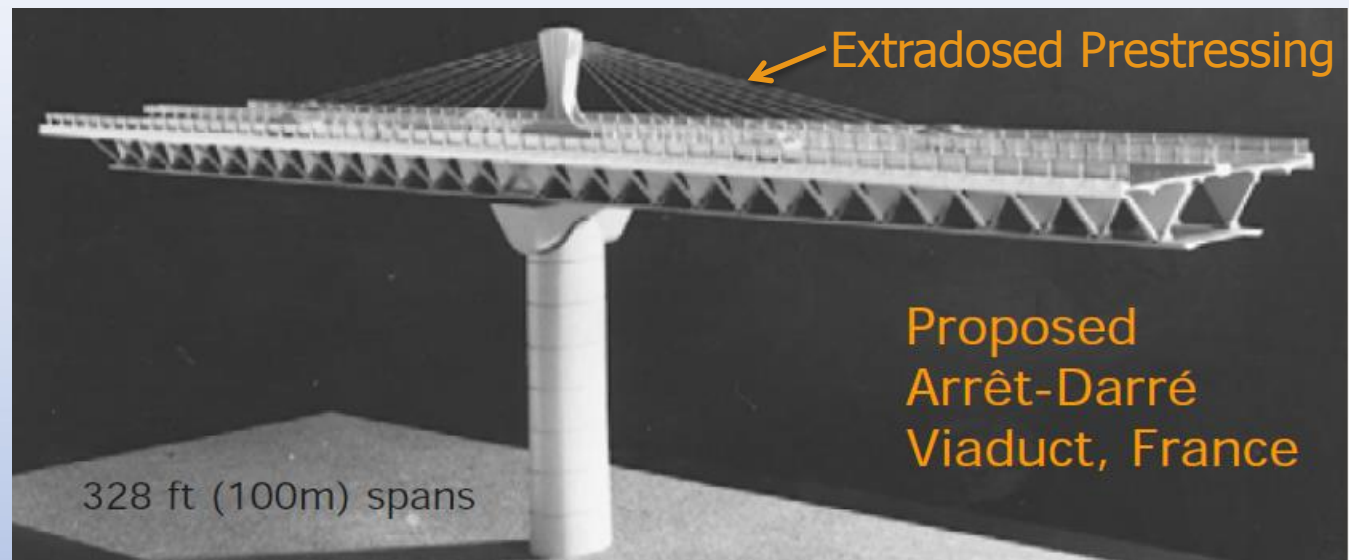
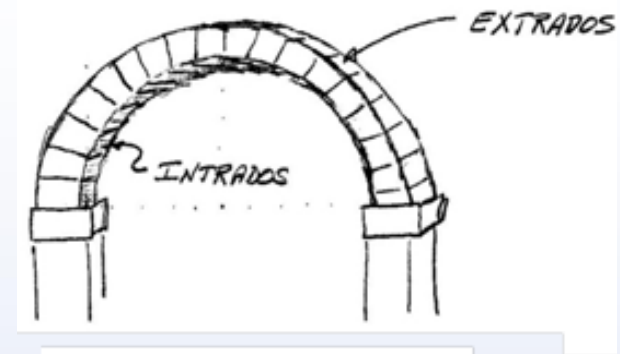
Defining an Extradosed Bridge

Jacques Mathivat , Journal of FIP, 1988

"Recent Developments in Prestressed Concrete Bridges"

Tower height is the defining element

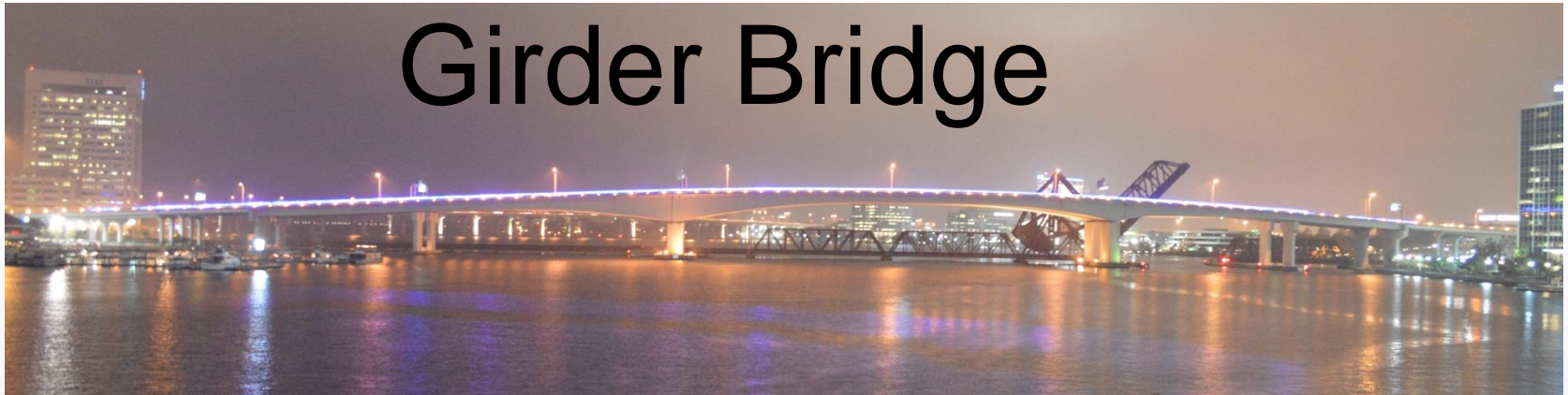
- Cable Stayed 1/5
- Extradosed 1/15



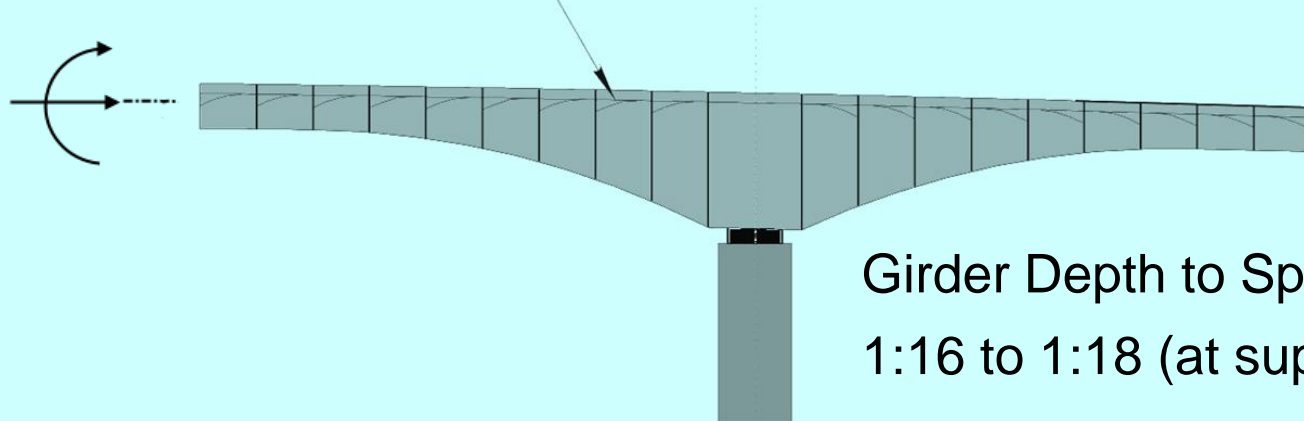
Characteristics of an Extradosed Bridge

- Shorter tower than cable stayed
- Shallower girder than a girder bridge, but deeper than a cable stayed bridge
- Flatter cables than a cable stayed bridge, and only over a portion of the span.
- Cables sized to prestress the deck
- Low fatigue ranges for cables
- Uniform size range for cables

Girder Bridge

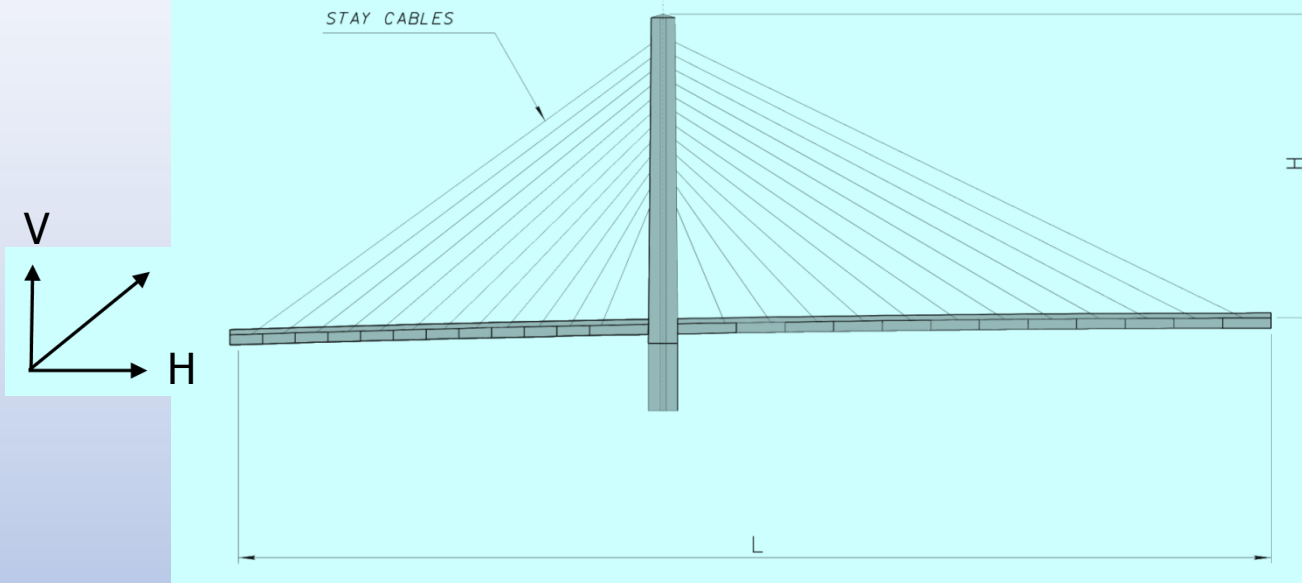


PRESTRESSING TENDONS



Girder Depth to Span
1:16 to 1:18 (at support)

Cable-Stayed Bridge



Girder
depth:
5 to 6 ft.
Tower
height to
Span:
1:4

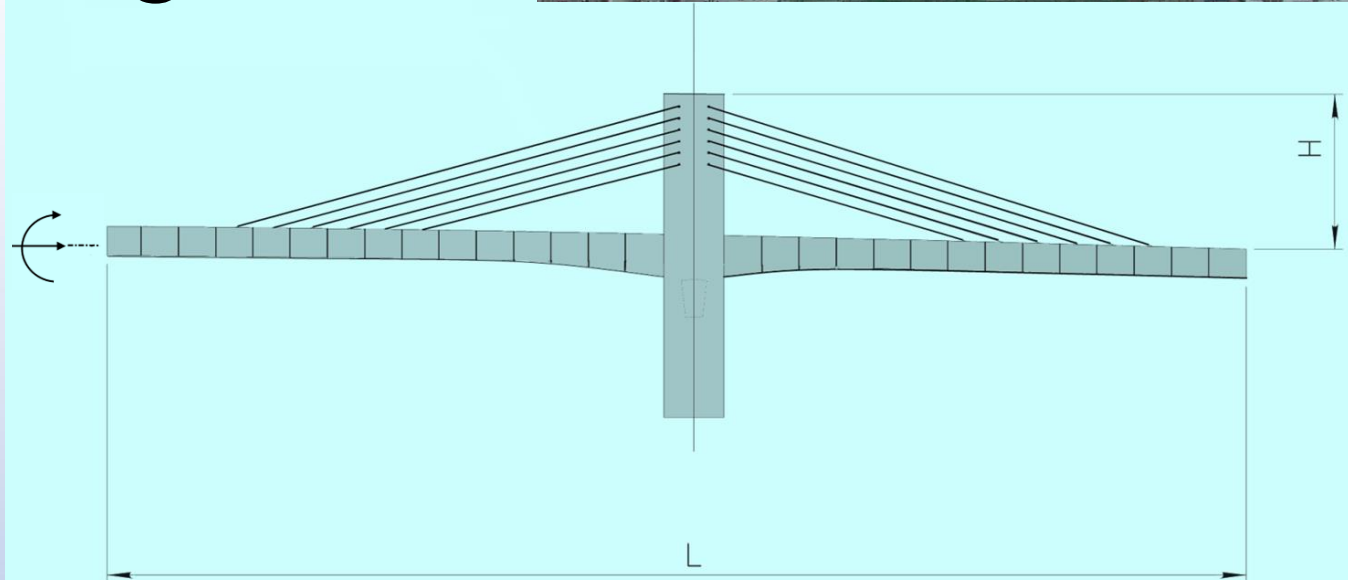
Extradosed Prestressed Bridge

Girder Depth
to Span:

1:30 to 1:35

Tower Height
to Span:

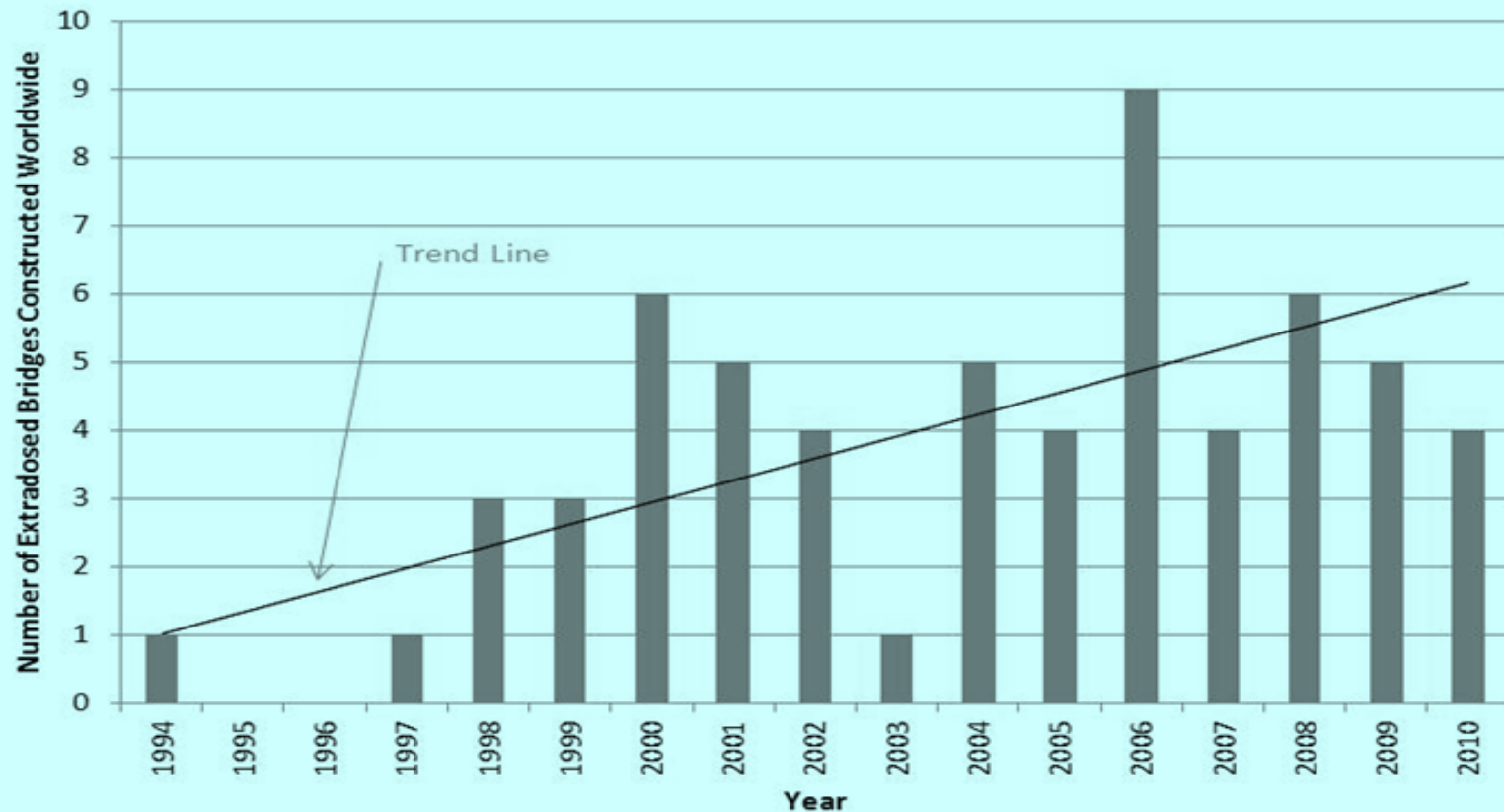
1:10 to 1:15



More than 60 Extradosed Bridges World-wide

- More than 30 in Japan
- More than 25 countries have at least one
- Currently 3 in the U.S.

Progression of Extradosed Bridge Construction



Representative Extradosed Prestressed Bridges

Odawara Port Bridge, Japan (1994)



Tsukuhara Bridge, Japan



Okuyama Bridge, Japan



Miykodogawa Bridge, Japan



Kiso and Ibi River Bridges, Japan



Rittoh Bridge, Japan



Sunnibergbrücke, Switzerland



Golden Ears Bridge, Vancouver, BC



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First U.S. Extradosed Bridge Pearl Harbor Memorial Bridge, New Haven CT



I-35 bridges over the Brazos River in Waco, Texas



Source: AECOM

St Croix River Bridge, Minnesota - Wisconsin

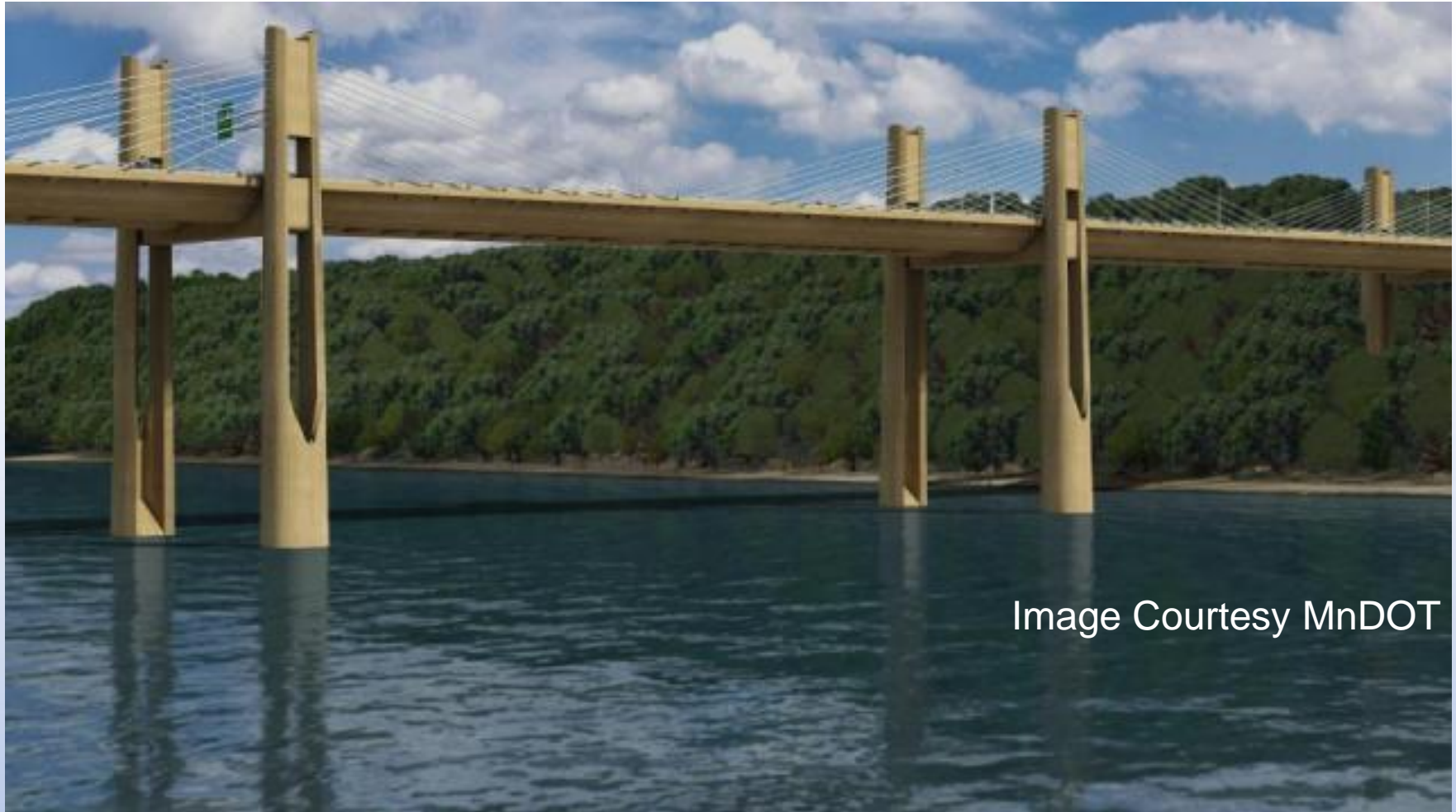


Image Courtesy MnDOT

Special Case Bridges (Non-Extradosed)



Barton Creek Fin-Back Bridge

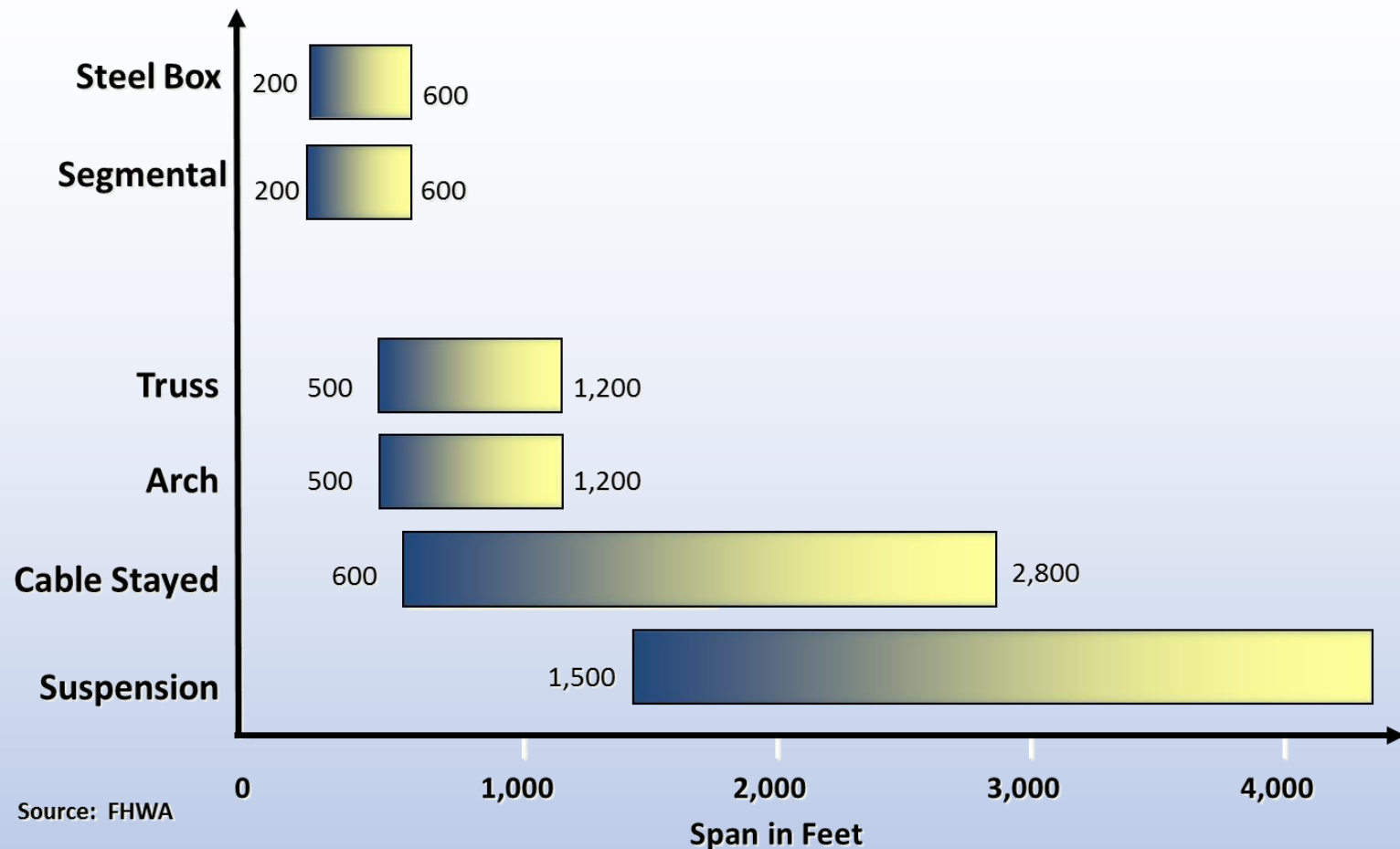


Ganter Bridge, Switzerland

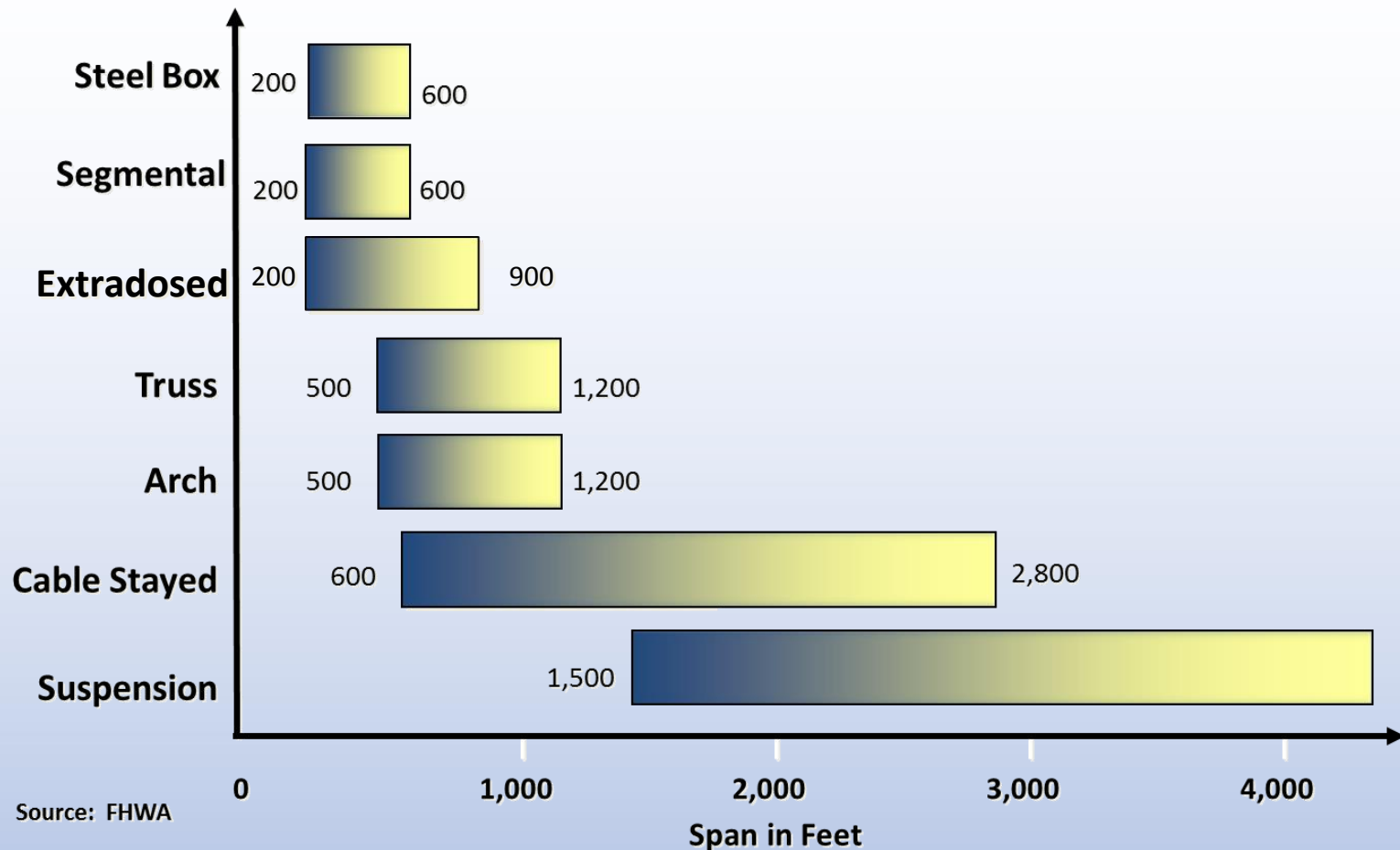
Key Proportioning Parameters and Design Considerations

- Span Lengths
- Side Span Ratios
- Multi Span Bridges
- Tower Height
- Girder Depth/Haunch
- Bridge Width
- Aesthetic Opportunities

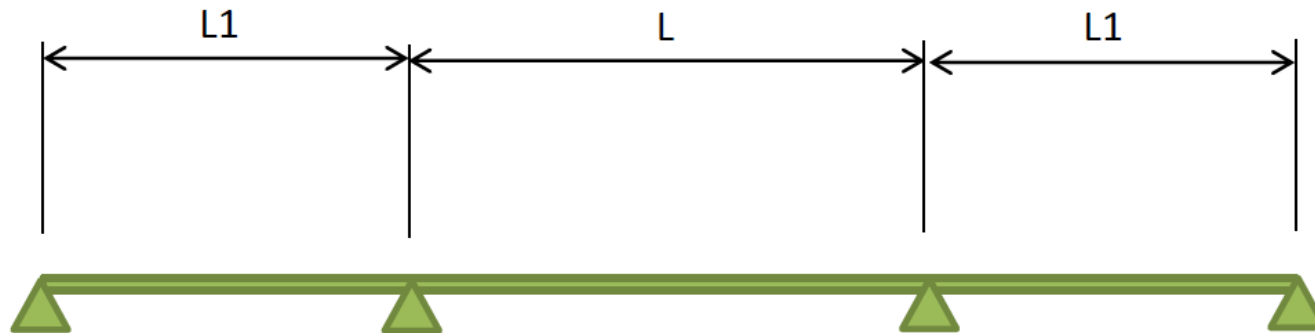
Economical Bridge Types



Economical Bridge Types



Side Span/Main Span Ratio



Girder Bridges

- Cast on falsework:
 $L1/L = 0.8$
- Balanced Cantilever: $L1/L = 0.65$

Cable Stayed Bridges

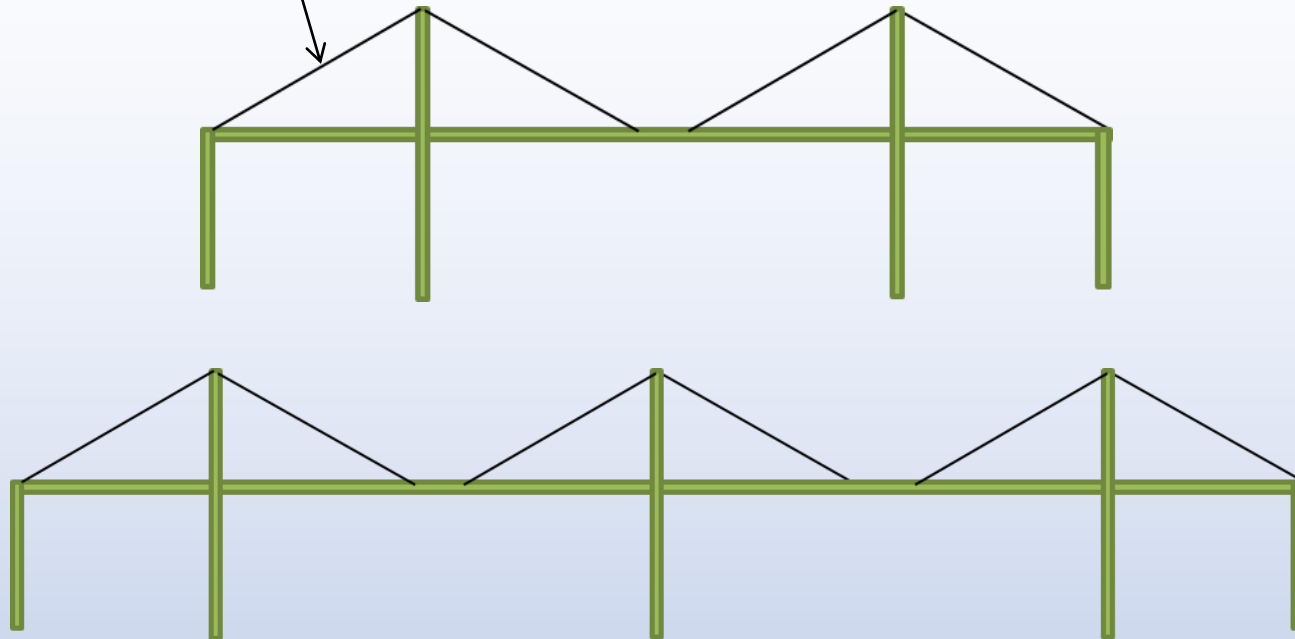
- Steel
 $L1/L = 0.35$
- Concrete
 $L1/L = 0.42$

Extradosed Bridges

- Mean $L1/L$ Ratio = 0.57
- One Std. Deviation = 0.45 to 0.69
- Use $L1/L = 0.6$

Consideration of Multi-Span Cable-Stayed Bridges

Backstay Cable



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Multi-Span Cable-Stayed Bridges

- Population of 1200 bridges
- Number of multi-span CS Bridges = 7



Rion-Antirion Bridge,
Greece



Ting Kau Bridge,
Hong Kong

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Multi-Span Extradosed Bridges

- Population of 63 bridges
- Number of multi-span Extradosed Bridges = 19

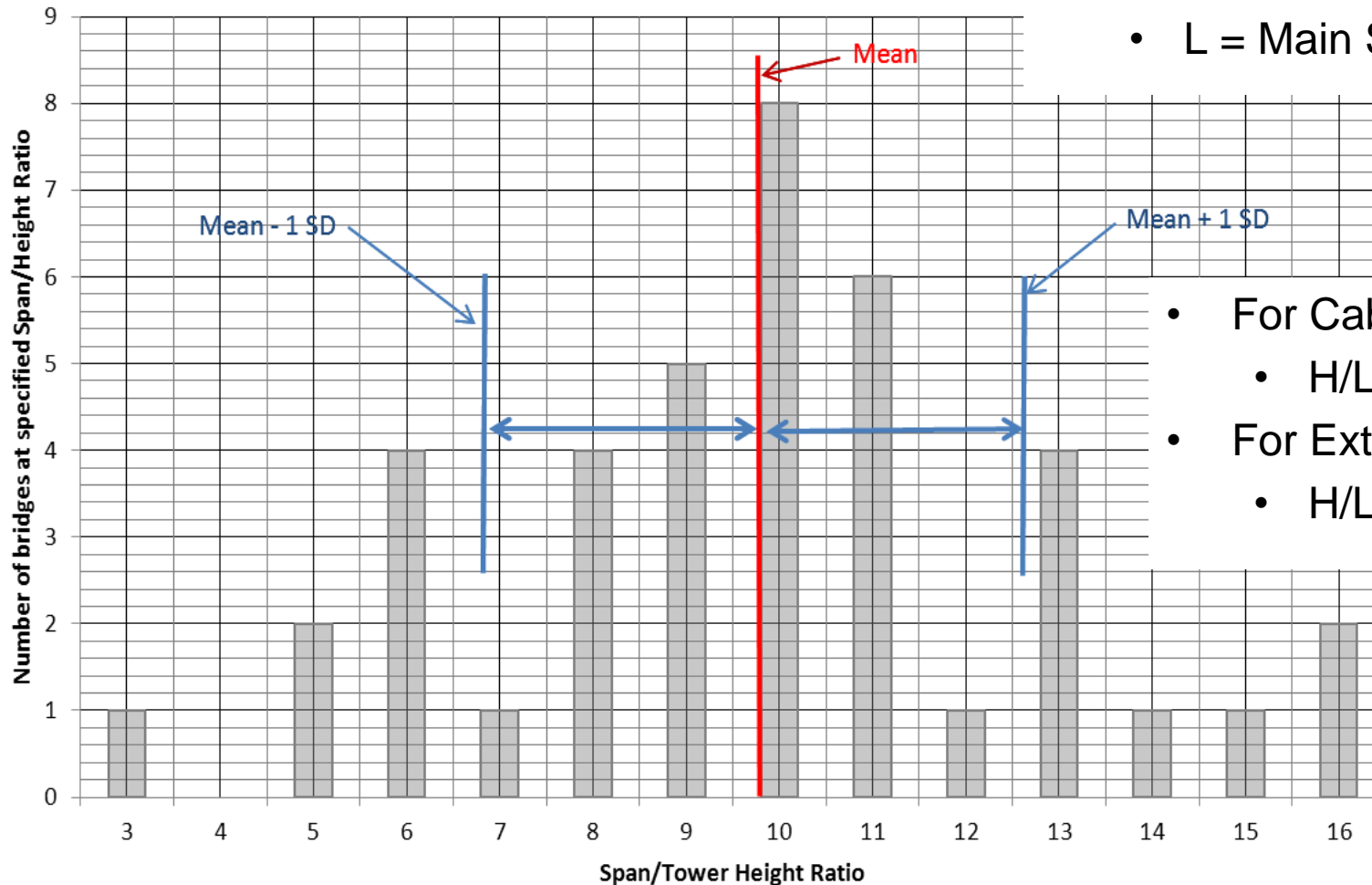


Kiso and Ibi River Bridges, Japan

Tower Height

Expressed as H/L

- H = tower height
- L = Main Span Length



- For Cable Stayed:
 - $H/L \approx 1/4$ to $1/5$
- For Extradosed:
 - $H/L \approx 1/10$

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Span/Depth Ratios for Extradosed Bridges

For Girder Bridges:

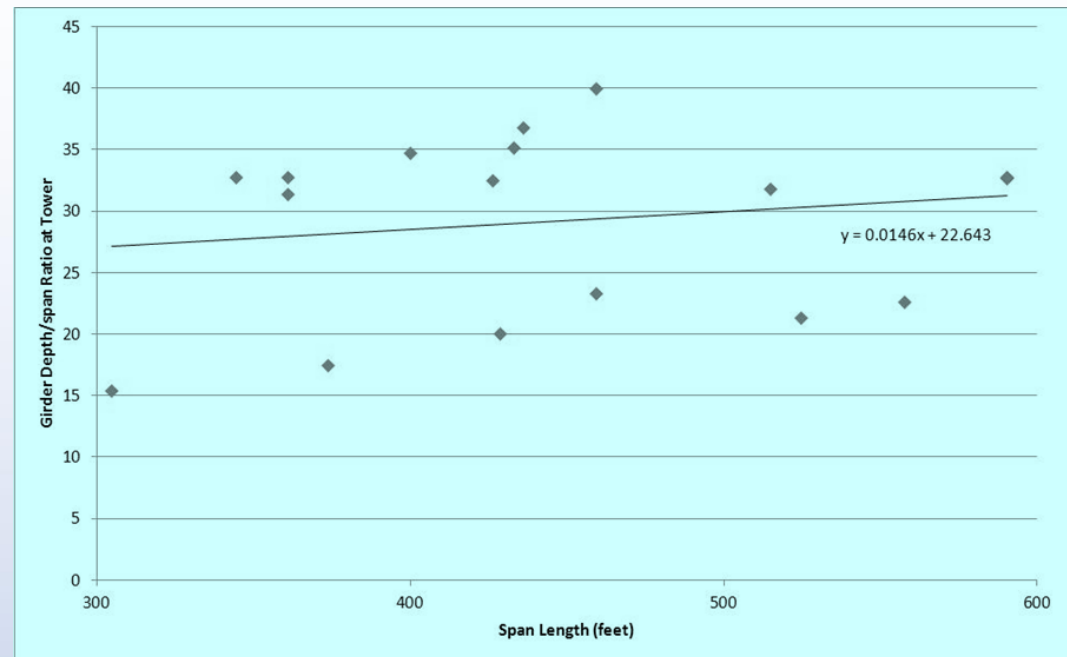
- Constant Depth: $S/D \approx 22$
- For Variable Depth:
 - $S/D \approx 17$ at pier
 - $S/D \approx 50$ at mid-span

For Cable Stayed Bridges:

- Range of depth/span
 ≈ 50 -250

For Extradosed Bridges:

- $S/D \approx 30$ at pier
- $S/D \approx 50$ at mid-span



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Typical Proportioning Parameters Extradosed Bridges

- Applicable Span Range: 200-900 ft.
- Side/Main Span Ratio: 0.6
- Tower Height/Span Ratio: 1:10
- Span/Girder Depth Ratio:
 - Midspan 1:50
 - At Tower 1:30
- Applicable to multi-span bridges

Aesthetics – General Structural Arrangement

Single Cable Plane



Twin Cable Plane



Three Cable Planes



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Aesthetics Stay Cable Arrangement

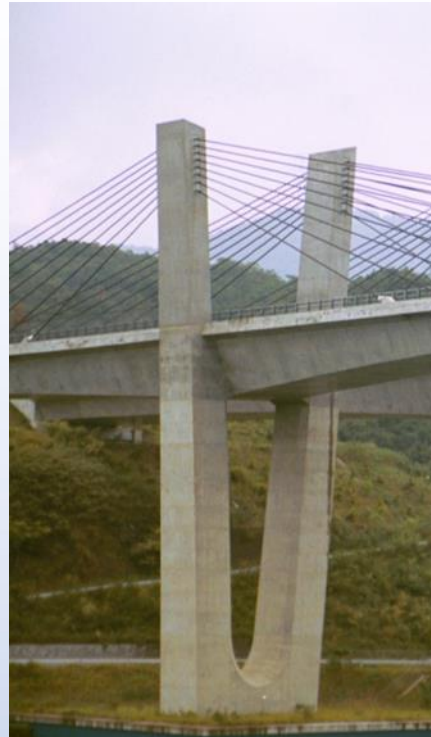
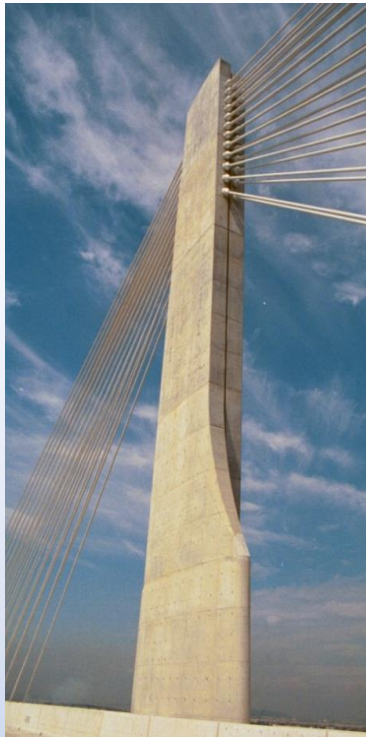


Fan Cable Arrangement



Harp Cable Arrangement

Aesthetics – Towers Arrangement/Shape



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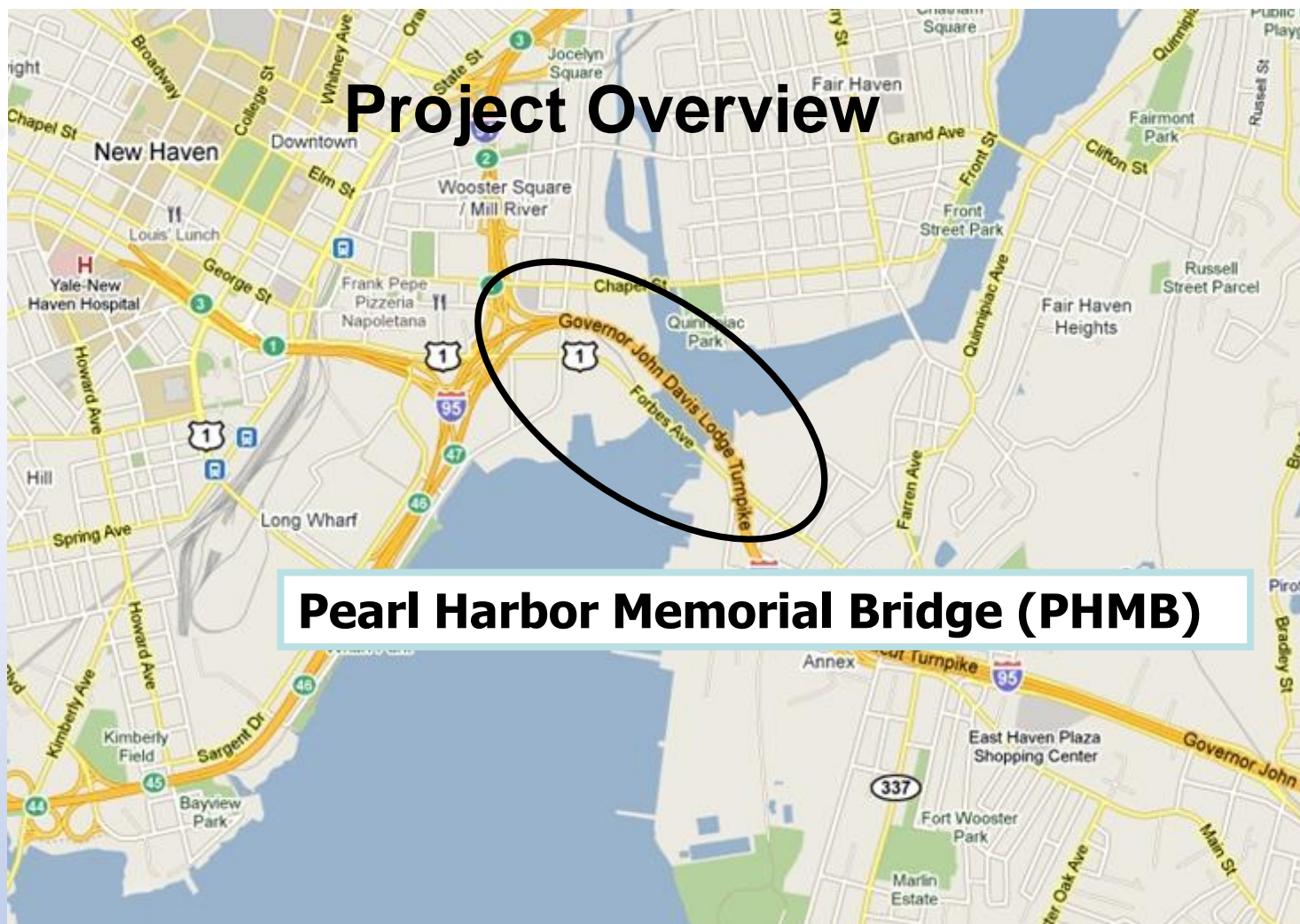
Case Study

Pearl Harbor Memorial Bridge, New Haven





Project Overview



Pearl Harbor Memorial Bridge (PHMB)

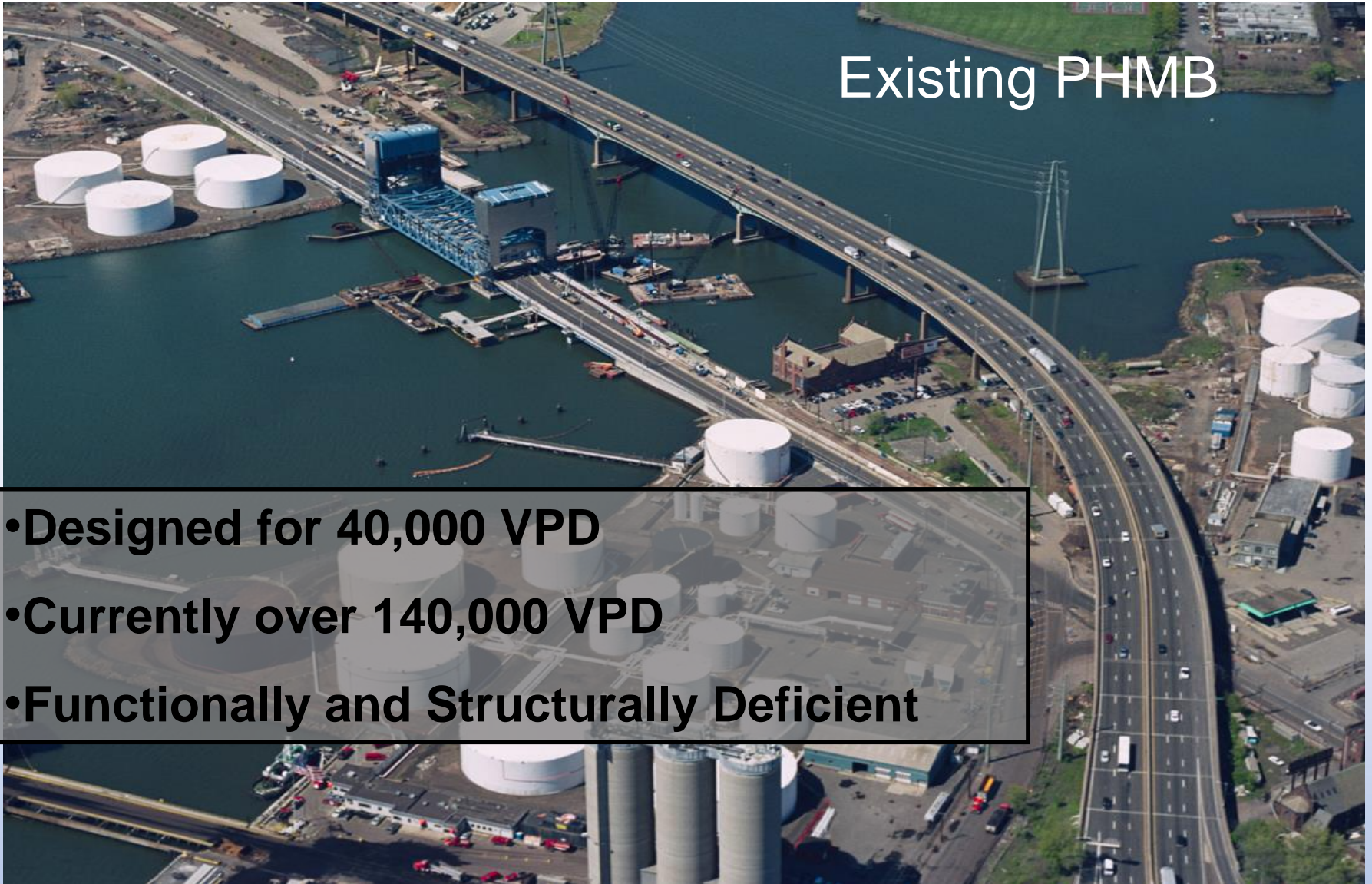
Existing PHMB

- Opened - 1958
- Main Span 387 ft.
- Longest Plate Girder Span in Western Hemisphere



Existing PHMB

- Designed for 40,000 VPD
- Currently over 140,000 VPD
- Functionally and Structurally Deficient



Replacement Bridge

- Increase from 6 lanes to 10 lanes
- Improved Safety
- Improved Navigation

Why an Extradosed Bridge for the PHMB?

- Longer Span Desired for Navigation
- Tower Height Restricted by Tweed Airport
- Girder Depth and Profile Controlled by Adjacent Interchange
- Economical Bridge Desired
- Bridge Worthy of Pearl Harbor Memorial Bridge Designation was Desired



Side Span / Main Span Ratio

$248.5' / 515.0' / 248.5' = 0.48$ Ratio

Recommended Ratio = 0.6

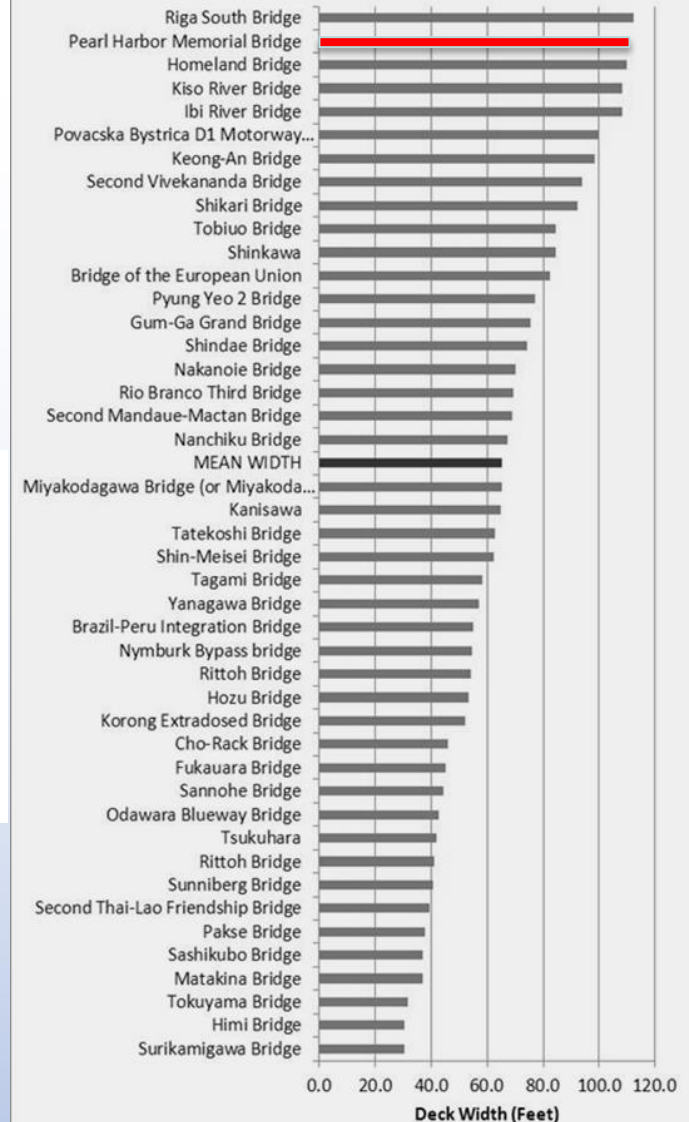
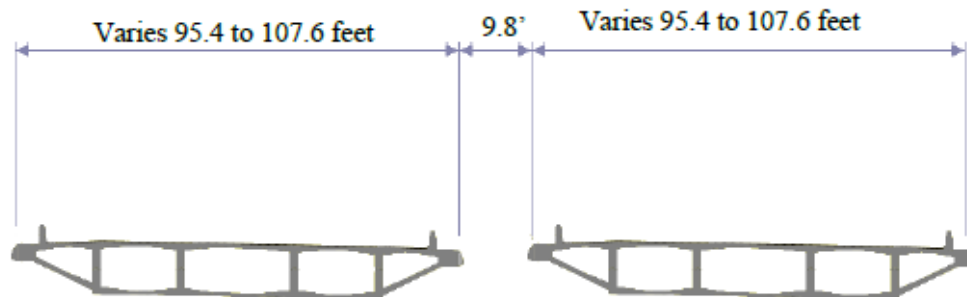
Typical Range = 0.45 – 0.69

Resulting Uplift = 570 kips (5% of the max. reaction)

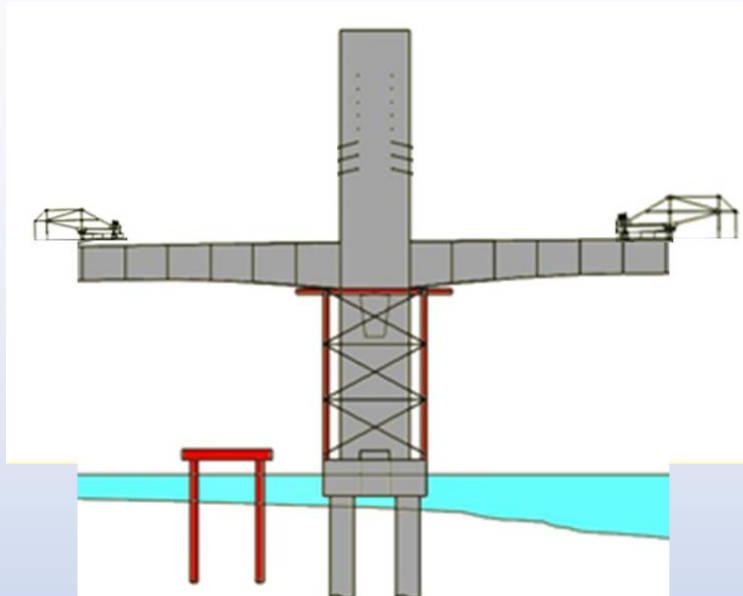
Counterweight Provided

Bridge Deck Width Girder Cross Section

Overall Roadway Width Varies 190-215 feet



Deck Depth / Haunch Arrangement



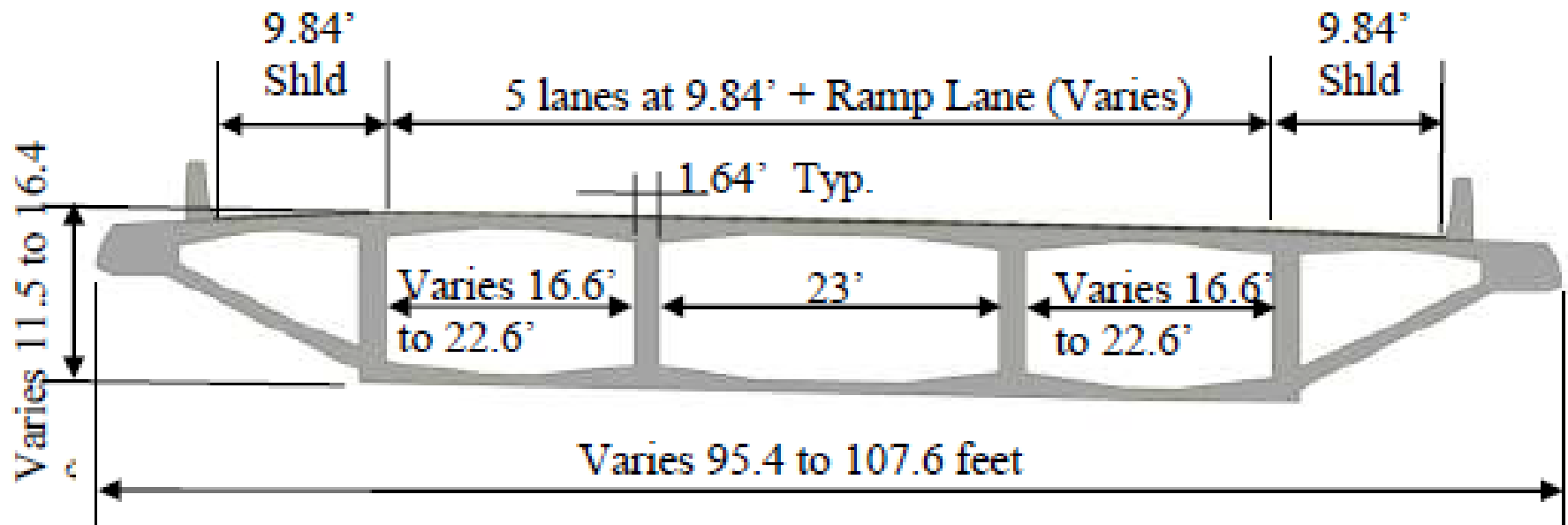
Recommended Span/Depth

- At Tower = 25-35
- At midspan 50

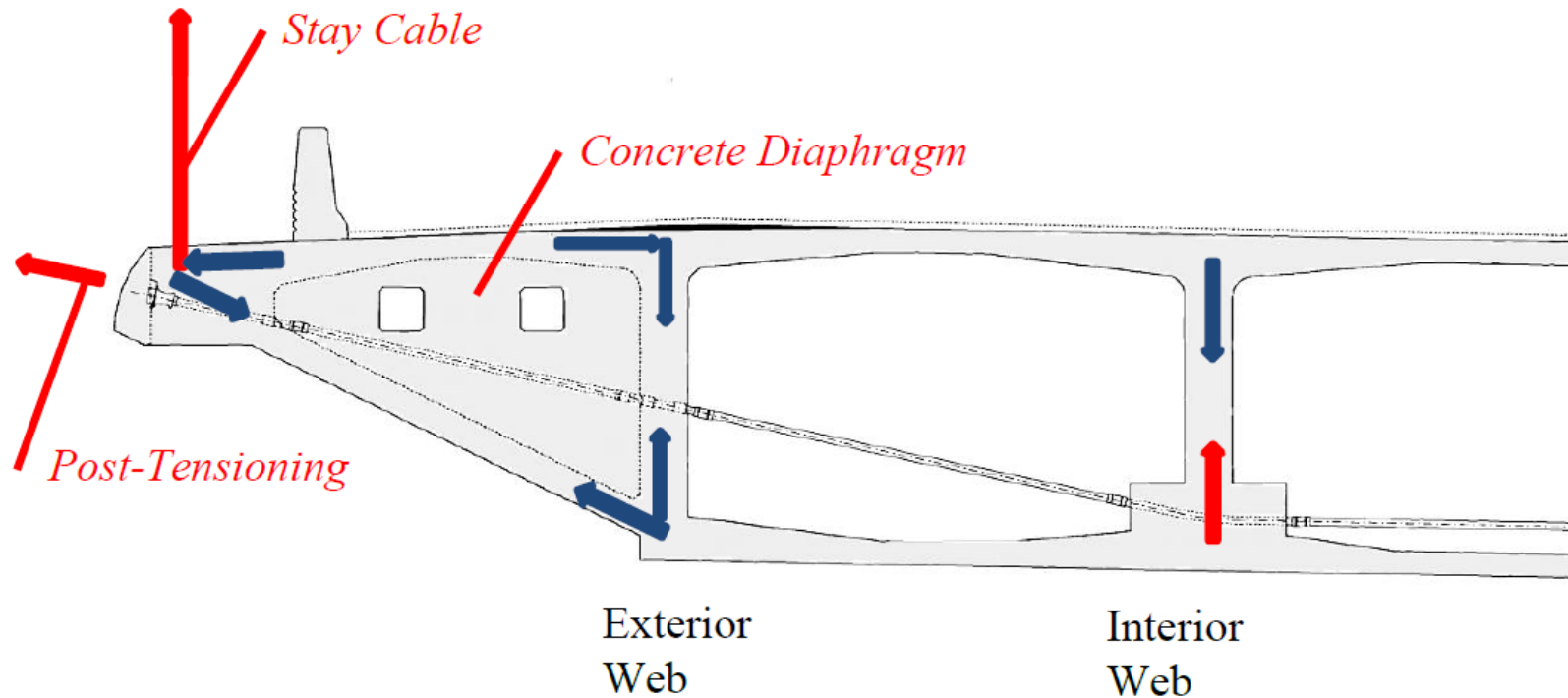
Provided Span/Depth

- At Tower = 31.4 (16.4' depth)
- At midspan = 45
- (11.5' depth)

Superstructure Cross-Section



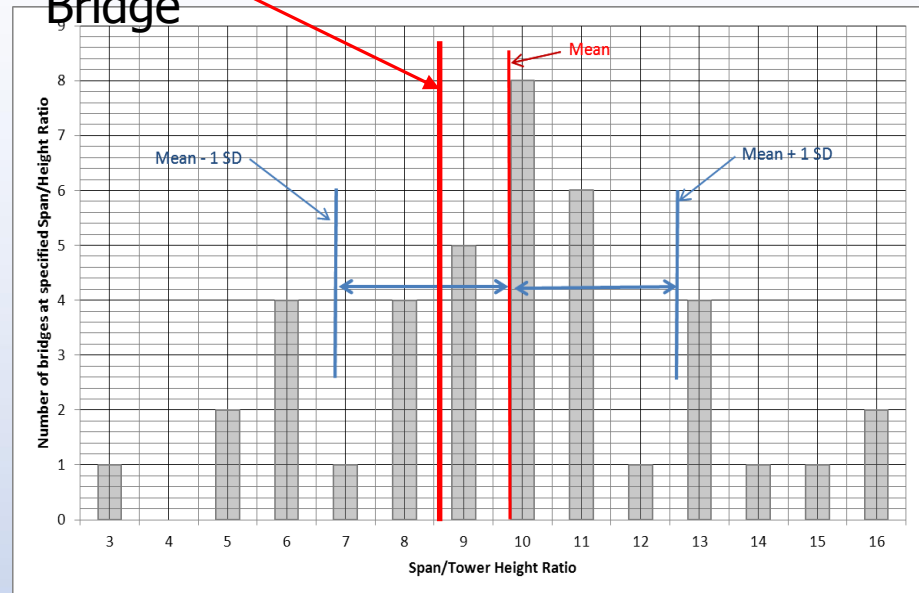
Transverse Post-Tensioning



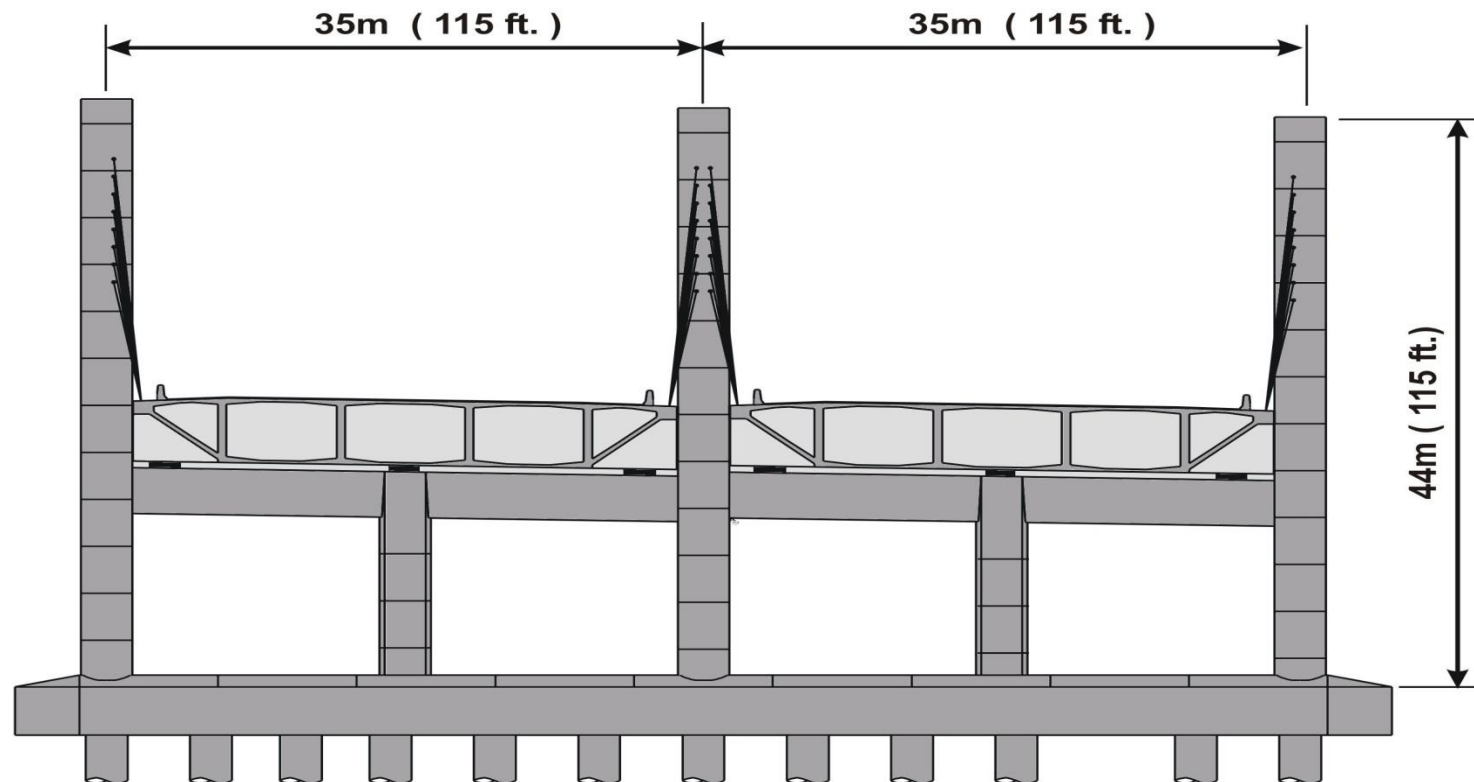
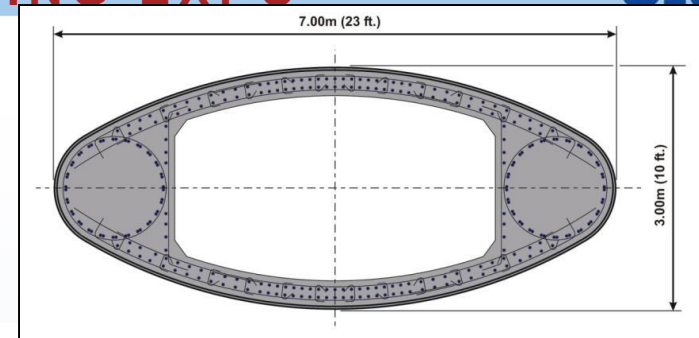
Tower Height

- Suggested $L/H = 10$
- Selected 60 ft. tower height
- $L/H = 8.6$
- ✓ Wide Heavy Deck
- ✓ Limit Fatigue Demand on Stays

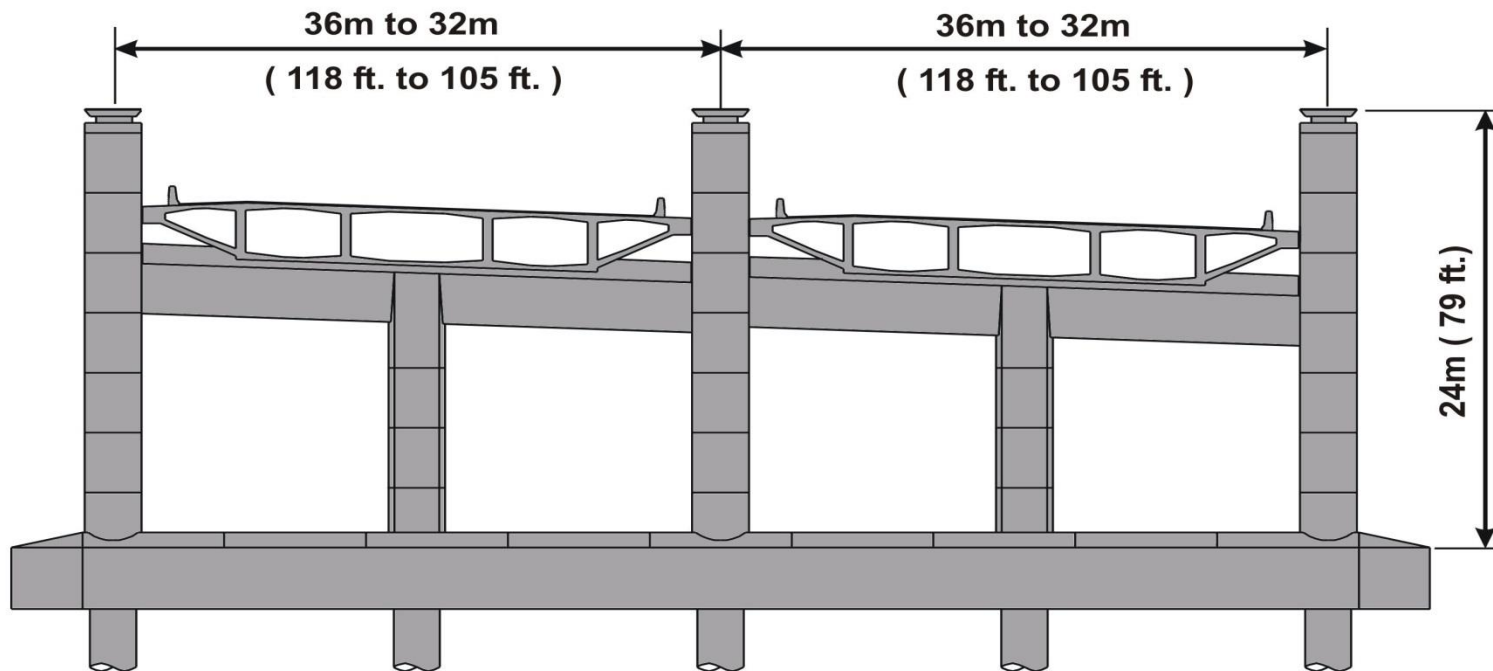
Pearl Harbor
Memorial
Bridge



Tower Elevation



Anchor Pier Elevation



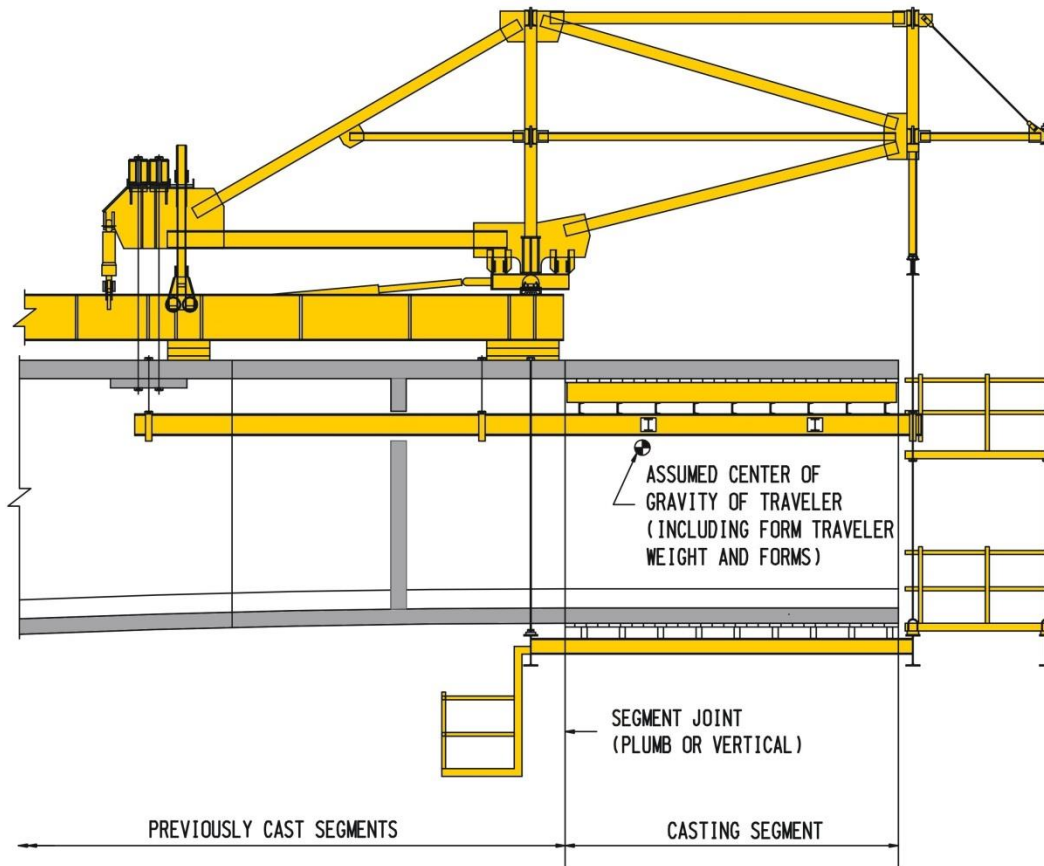
Stay Cable Design Criteria

- 0.6" (15mm) Grade 270 Strand
- Greased and Individually Sheathed
- Co-extruded PE pipe
- Jacked Strand-by-Strand at tower
- Stay Design Stresses
 - 0.55 f's for AASHTO Group I
 - 0.60 f's other Load Groups
 - 0.60 f's construction or stay replacement

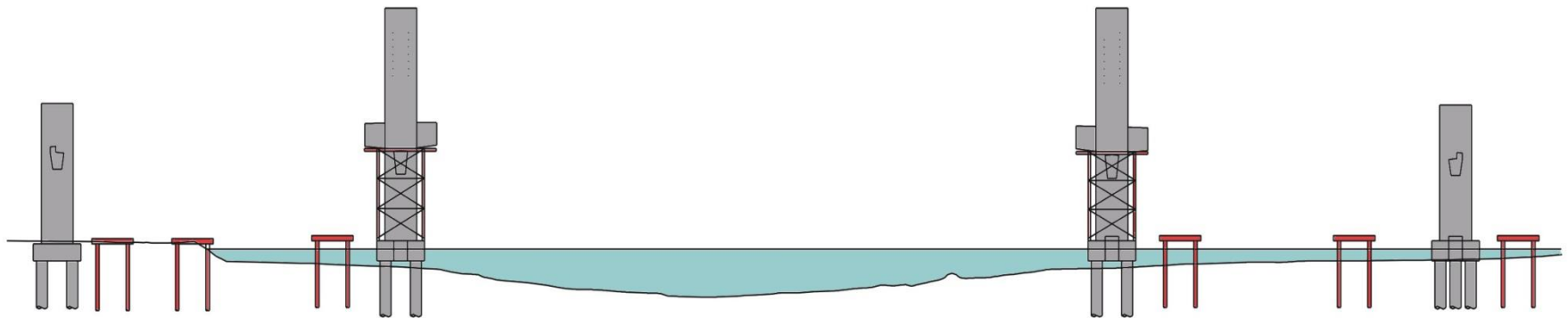
Erection



Form Traveler Construction

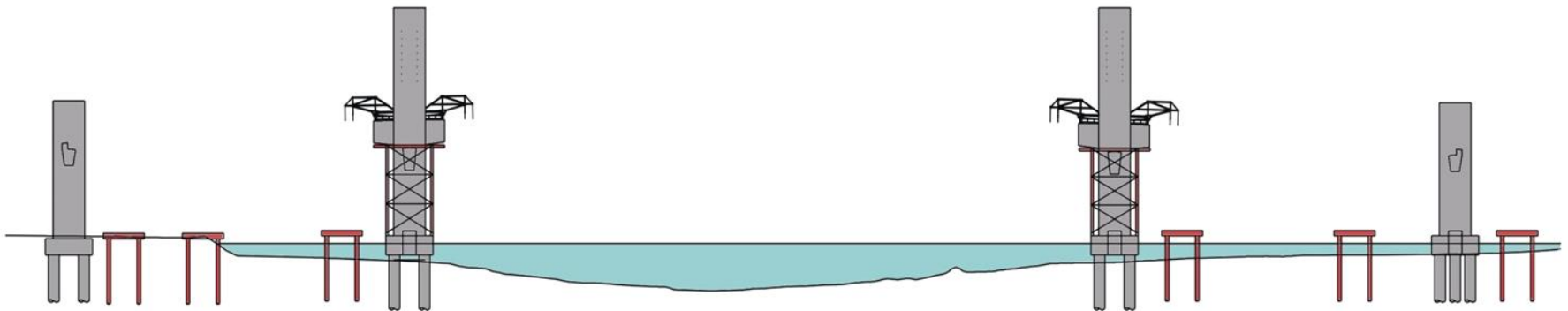


Main Span Construction Sequence



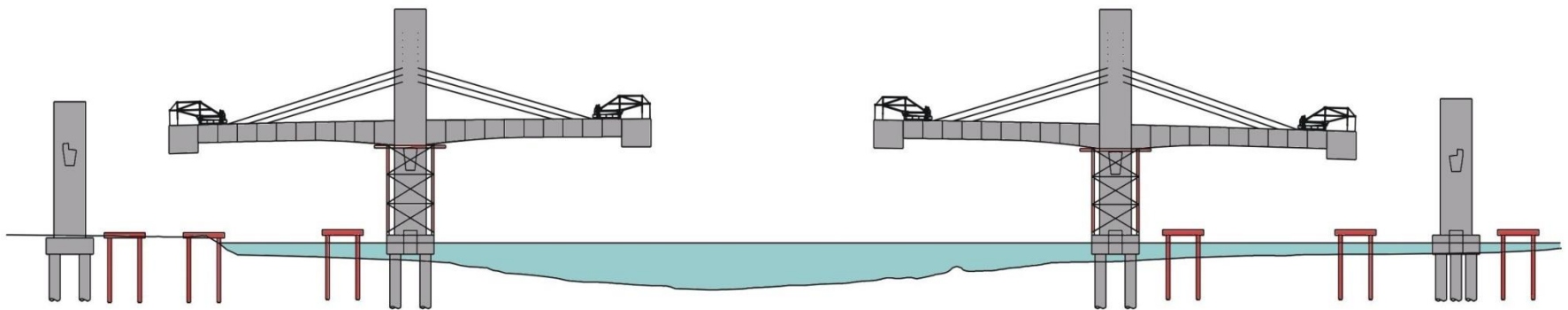
- Stage 1 - Construction of Substructures and Pier Tables

Main Span Construction Sequence



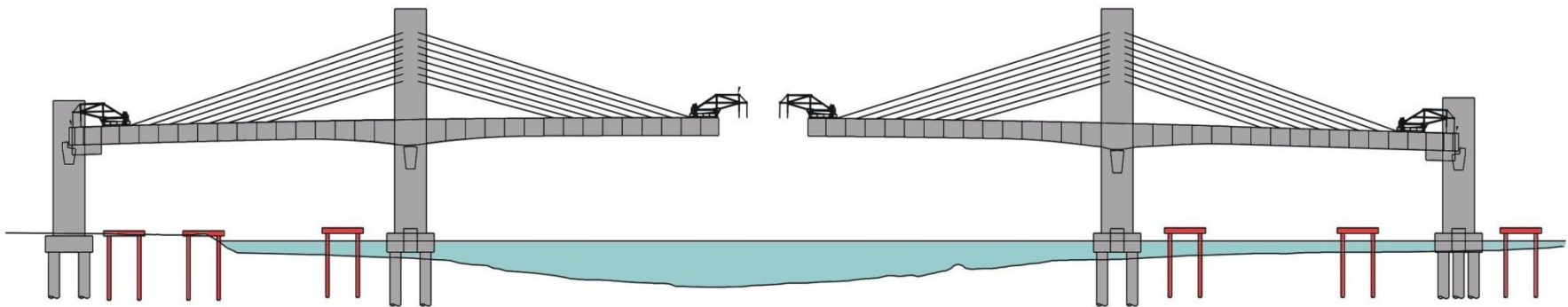
- Stage 2 - Assembly of Traveling Forms

Main Span Construction Sequence



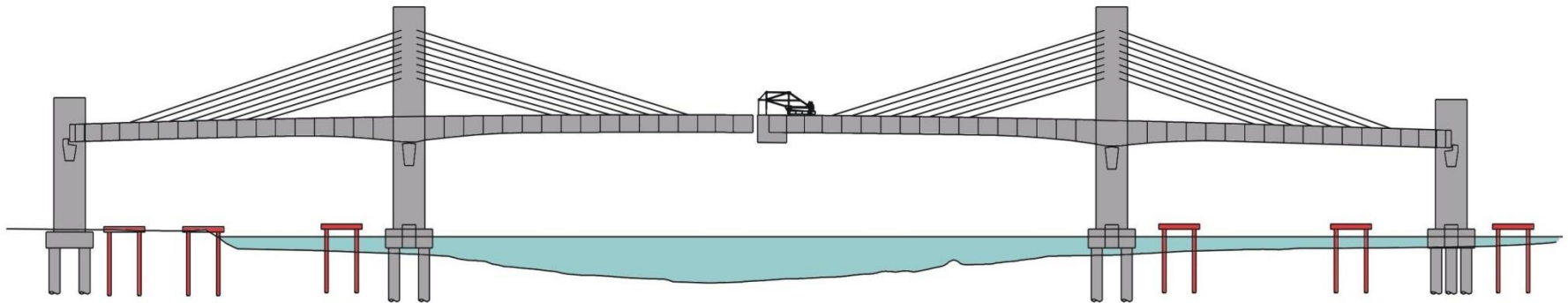
- Stage 3 - Balanced Cantilever Construction and Cable Installation

Main Span Construction Sequence



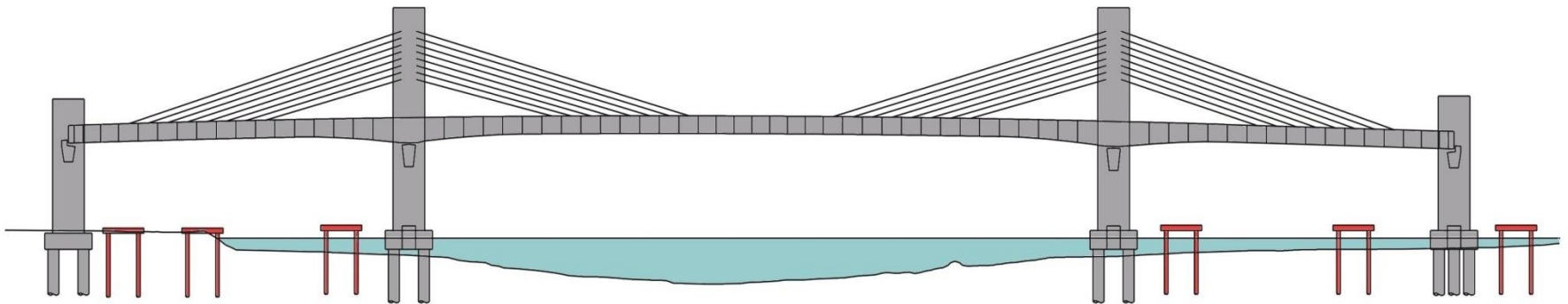
- Stage 4 - Continuation - Cantilever Construction

Main Span Construction Sequence



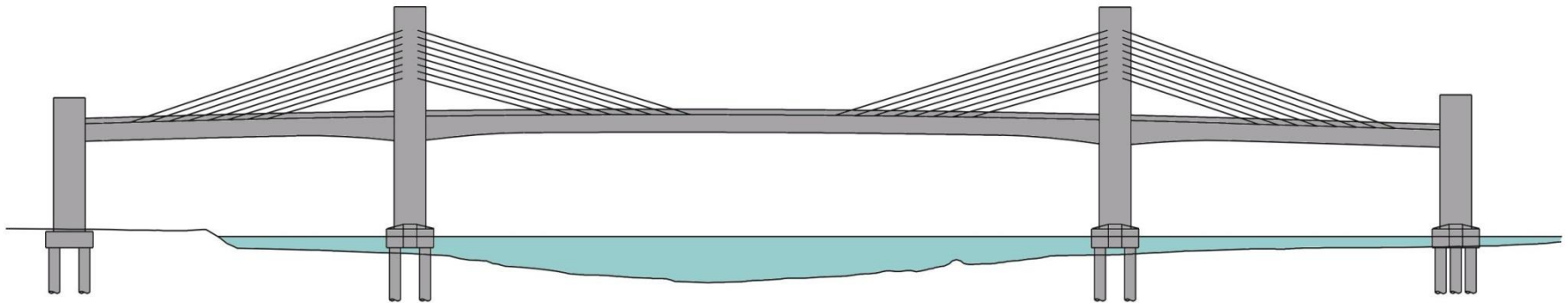
- Stage 5 - Closure at Side Span

Main Span Construction Sequence



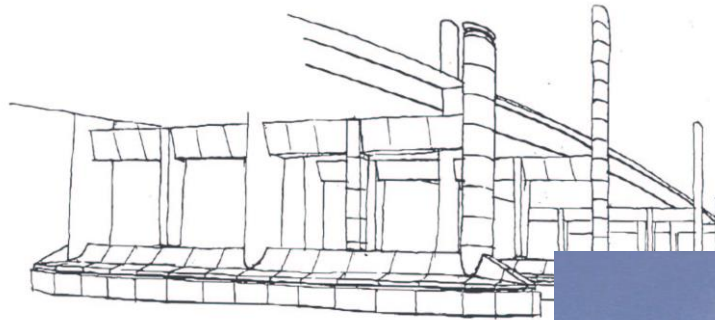
- Stage 6 - Closure at Main Span

Main Span Construction Sequence



- Stage 7 - Finishing Works

Aesthetics





Florida
Department of
Transportation



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URS



KEY BRIDGE PARAMETERS AND QUANTITIES

Superstructure weight (ea. deck)= 54.2 klf

Equivalent concrete depth for girder = 3.4'

Longitudinal Post-Tensioning= 11 psf

Transverse Post-Tensioning= 0.9 psf

Weight of stay cables= 3.5 psf

FDOT DESIGN TRAINING EXPO

Contract B1

Contract Award:

- April 2008

Owner:

- ConnDOT

Contractor:

- Cianbro/Middlesex JV III

Designer:

- URS

Program Manager:

- Parsons Brinckerhoff

CE&I:

- Prime: Lochner
- Sub: FIGG

Original Contract Value:

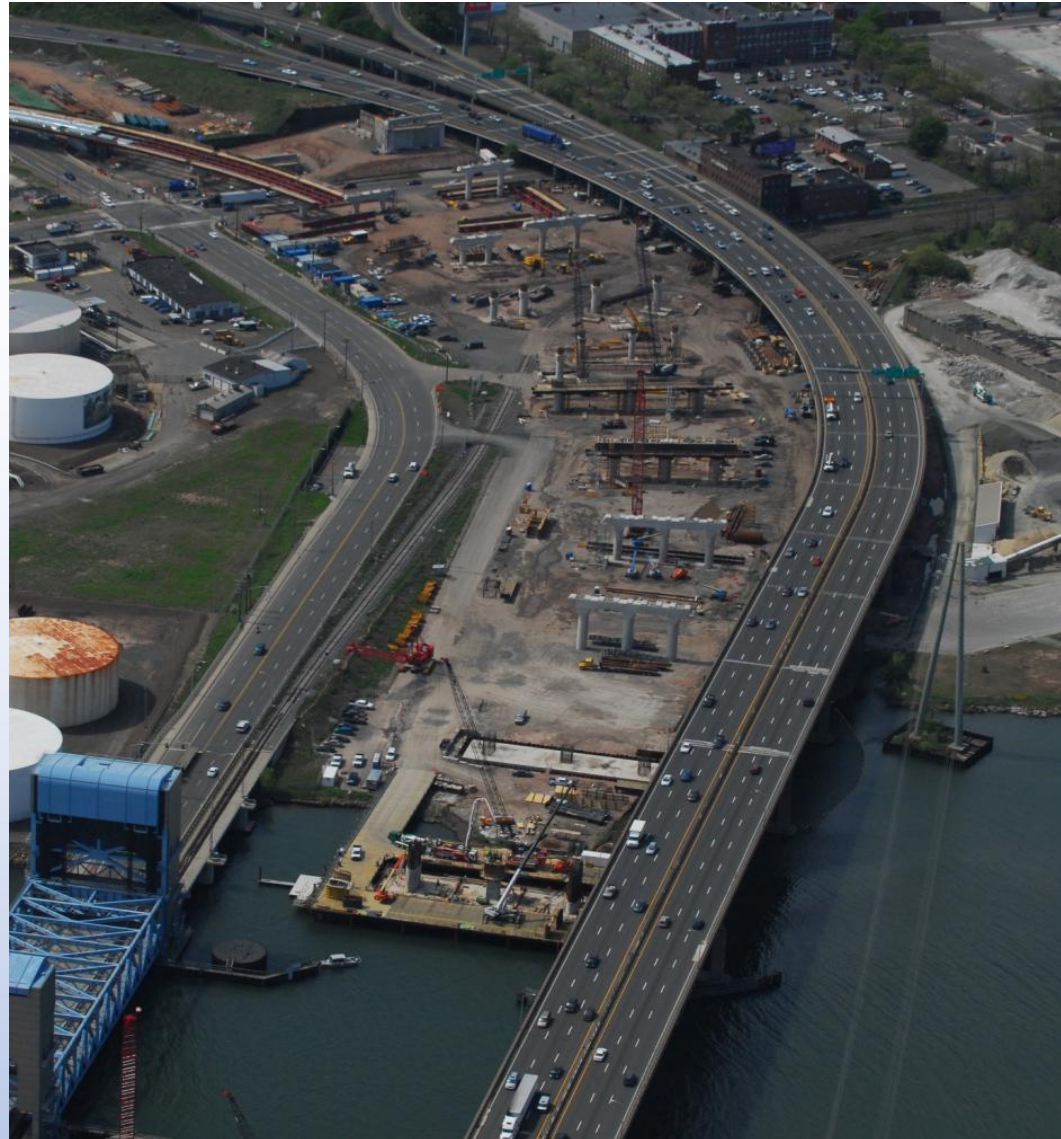
- \$137,494,973

Final Contract Value:

- \$136,385,903

Final Completion Date

- August 18, 2011
- 34 days early



FDOT DESIGN TRAINING EXPO

Contract B

Contract Award:

- July 2009

Owner:

- ConnDOT

Contractor:

- Walsh/PCL JV II

Designer:

- URS

Program Manager:

- Parsons Brinckerhoff

CE&I:

- Prime: Lochner
- Sub: FIGG

Original Contract Value:

- \$416,691,984

Current Contract Value:

- \$416,805,470

Current Completion Date

- June 30, 2015



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Tower Foundations: Drilled Shafts



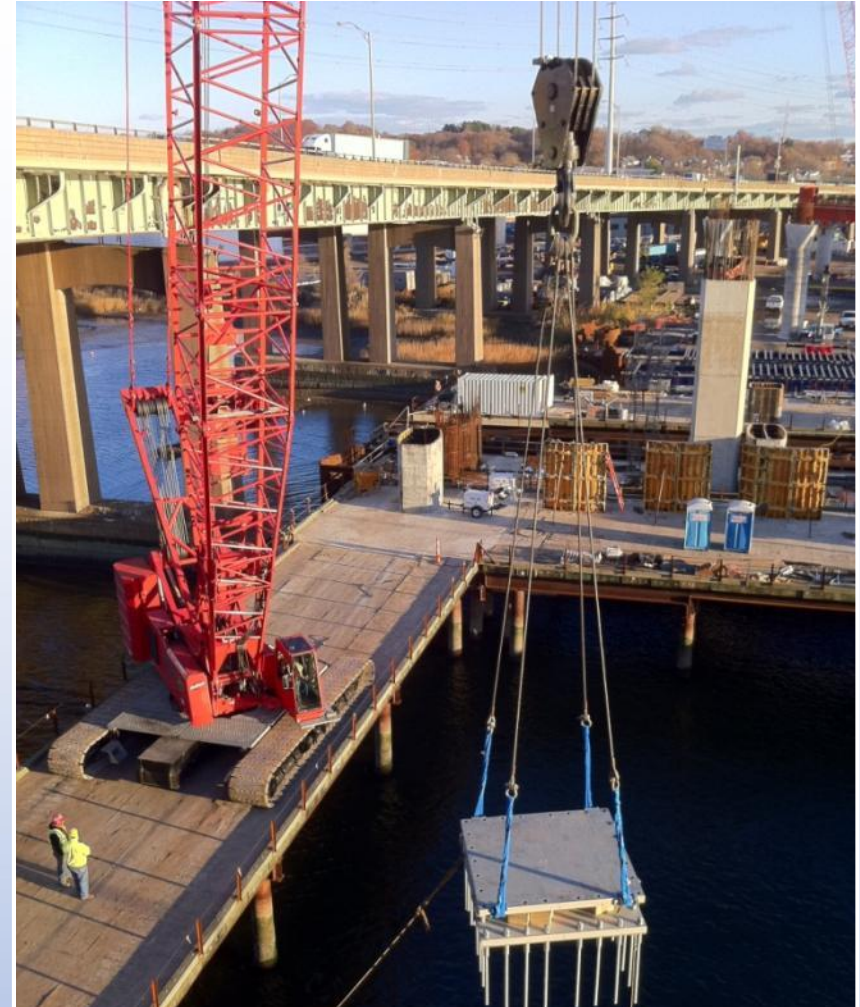
Tower Foundations



Tower Construction

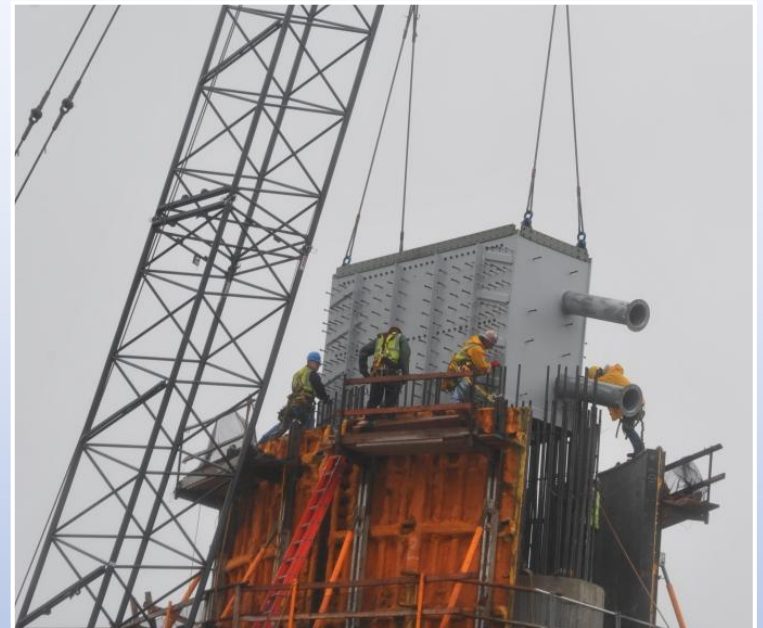


Bridge Bearings



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Tower: Stay Anchor Box



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Pier Table Construction



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Pier Table Construction

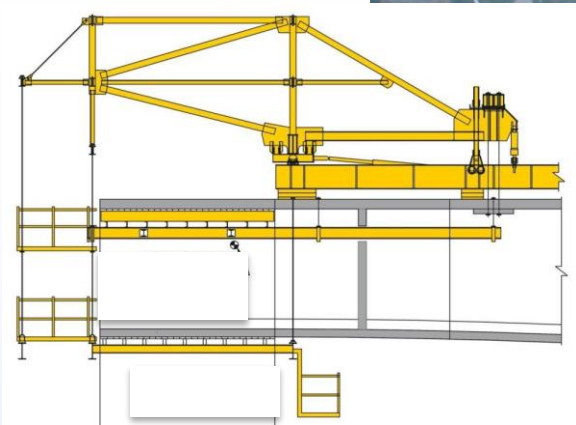


Out-of-Balance Supports



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Balanced Cantilever Construction with Form Traveler



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Balanced Cantilever Construction



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Side Span - Main Span Closure



Main Span Closure



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Northbound Bridge Opened 22 June 2012



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Existing Bridge removed – Southbound Bridge
Scheduled for June 2015 Completion



Concluding Remarks – Extradosed Bridges

- Extradosed Bridges are an Emerging Technology
- Their practicality has been proven by numerous prototype bridges constructed in more than 25 countries
- Economical in the 200-900 foot span range
- Advantageous for Multi-span Bridges
- Basic Proportioning Well Understood
- Stay Criteria Included in Latest PTI Specifications
- Have Opportunities for Unique Visual Presentations

Questions

